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A NOTE ON SOME EXPERIMENTS DEALING WITH SULPHUR TREATMENT OF A SOIL AND ITS EFFECT ON WHEAT YIELD.

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Art. IV.—*A Note on some Experiments dealing with Sulphur Treatment of a Soil and its effect on Wheat Yield.*

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(Communicated by Professor S. M. Wadham.)

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Contents.

introduction.

A plot of land in the grounds of the Agricultural Department of Melbourne University has had wheat grown on it continuously for fourteen years. Latterly the yield has been poor, and the plants have produced a large proportion of sterile heads. It was thought that this might be due to the presence in the soil of fungi, causing foot and root rot diseases. The present investigation was undertaken to test the effect of certain soil treatments with the possibility in view of finding a method which would reduce the disease without adversely affecting the crop. In certain English soils treatment with sulphur (1) and sulphuric acid (2) has reduced Wart Disease of potatoes caused by *Synchytrium endobioticum,* an organism which infects from the soil. There was, however, a general tendency for the heavier treatments to depress the yield. Treatments which had given promising results with Wart Disease were tried in the present experiment, which was carried out at the School of Agriculture, University of Melbourne, during the tenure of the Australian Fellowship of the International Federation of University Women.

Present Investigation.

Sulphur was applied to certain plots as flowers of sulphur, and sulphuric acid containing equal quantities of the element sulphur

was applied to others. Lest the acid should affect the disease but at the same time make the soil too acid for fertility, some plots after treatment with acid were left for a few days in which it might act on the organisms, and then equivalent amounts of calcium carbonate were applied to counteract the acidity. Controls with calcium carbonate alone were laid down. The effect of the fertiliser ammonium sulphate was also tested for comparative purposes.

Soil.

The land used in the present investigation is enclosed in wire netting to protect the crop from birds. It carried manurial tests about 1912. After this the soil was very thoroughly mixed and cultivated to obtain uniformity. It has borne an annual crop of wheat since 1914, with an application of 1-2 cwts. per acre superphosphate about every second year, and of 1-2 tons per acre of lime about 1923, and an application of road scrapings about the same time. The soil consists of a light loam, dark grey in colour, and of very even texture, which is not typical of the district. The crops appear to have deteriorated within recent years, and are recorded as poor in 1926 and 1927.

Treatment.

The quantities of each chemical applied were calculated so as to supply the element sulphur to the soil in the proportion of 0·05, 0·10, and 0·15%. Treatment of the soil was effected between June 23rd and 26th, 1928. Plots one yard square were marked off by means of two galvanised iron strips 9 inches wide and two yards long, bent in the middle at right angles, so that when fitted together they made a square. These were pushed into the ground, and 300 lbs. of soil were removed from the plot, weighed, spread out on a galvanised iron tray 48 in. x 48 in. and 6 in. deep, and well mixed with the various chemicals. The soil was then replaced in the plots, and the surrounding strips removed. The control plots were treated in the same way, omitting the chemical treatment. Sulphur, calcium carbonate and ammonium sulphate were applied in the solid state. Sulphuric acid was first made up to 2½ litres in water.

Federation wheat was sown on June 30th. In each plot there were four rows eight inches apart, with sixteen grains in a row. Observations were made at least fortnightly throughout the season, and the crops harvested on 11th December, when pH determinations of the plots were made. Sulphate estimations were made on certain plots before sowing and after harvest.

A general survey of the disease present was made by a superficial examination of the plants before harvest. After harvest the bases of all the wheat plants were cut off about an inch above the crown, and those obtained from each row were put in separate damp chambers. After a period for incubation these were examined for parasitic fungi.

Observations.

Germination was observed to have taken place very evenly in about eighteen days, and during the first six weeks no differences could be detected between the controls and the treated plots. After eight weeks differences began to show, and the plants on plots treated with sulphur, sulphuric acid both alone and with lime, and with ammonium sulphate developed a deeper green, and became taller and more robust than the controls or those which had received lime alone. These differences increased as the season advanced, so that the general appearance of the plots was not unlike that of plots at Rothamsted to which a nitrogenous manure had been applied, causing the production of a dark green robust growth.

Crops.

The crops obtained from the different plots are shown in the table. The five controls gave a consistently low yield, varying from 29·2 to 61·3, with an average of 47·0 gms. per square yard of total straw and grain. The grain alone averaged only 1gm. per square yard, or approximately 0·18 bushels, or 10 lbs., per acre. The pH did not vary much round an average of 7·57.

Sulphur treatment gave a remarkable increase in both straw and grain, each of which increased with the amount of sulphur applied. The largest total increase amounted to over 800%, while the grain in the most heavily treated plot amounted to 162·6 gms. per square yard, or 28·9 bushels per acre. The acidity of the soil increased with the amount of sulphur added, as did the sulphate content of the soil.

Sulphuric acid supplying 0·15 and 0·10% sulphur gave a large increase in the crop. Duplicate plots giving 0·1% sulphur showed rather large differences in final yield, though up to the last month they looked very similar. This may have been partly due to the fact that the one producing the larger crop was next to a path and the other was situated between two plots bearing heavy crops so that lack of moisture may have been a limiting factor. No explanation can be offered for the difference in pH or the fact that the acidity of a plot receiving 0·1% S as sulphuric acid is greater than that in the plot receiving 0·15%S. The sulphate content of the latter was higher than the former, and corresponded roughly with the amount of acid added. A larger number of duplicate plots are needed to give quantitative results. The main result of the treatment with sulphuric acid is a large increase of crop corresponding with increased soil acidity.

The addition of lime after treatment with sulphuric acid did not reduce the crop, as compared with that produced when sulphuric acid was applied alone, but in general gave a slight and possibly insignificant increase. The addition of calcium carbonate equivalent to the acid applied did not restore the soil to its

YIELD AND pH OF PLOTS TREATED WITH SULPHUR, SULPHURIC ACID ALONE AND WITH LIME, LIME ALONE AND AMMONIUM SULPHATE.

TABLE I.

TREATMENT	Sulphur applied as % of soil	pH	YIELD in grams			Bushels grain per acre
			Straw	Grain	Total	
Control	—	7·66	55·0	0	55·0	
	—	7·77	46·5	0·1	46·6	
	—	7·42	58·3	3·0	61·3	
	—	7·57	41·1	1·9	43·0	
	—	7·47	29·1	0·1	29·2	
Average	—	7·57	46·0	1·0	47·0	0·18
Sulphur	0·15	5·69	271·4	162·6	434·0	28·9
	0·1	5·98	169·5	76·3	245·8	13·5
	0·1	6·43	111·2	33.2	144·4	5·7
	0·05	6·77	64·5	5·9	70·4	1·0
H_2SO_4	0·15	6·60	240·1	71·9	312·0	12·8
	0·1	5·52	237·9	140·1	378·0	24·9
	0·1	6·65	217·0	66·5	283·5	11·8
	0·05	7·17	80·5	4·2	84·7	0·7
$H_2SO_4+CaCO_3$	0·15	6·61	226·7	148·7	375·4	26·4
	0·1	6·59	175·5	115·2	290·7	20·4
	0·05	6·98	72·8	1·1	73·9	0·19
$CaCO_3$	0·15	—	69·8	1·5	71·3	0·19
	0·1	7·62	54·6	9·8	64·4	1·7
	0·05	7·56	48·0	0·3	48·3	0·05
Ammonium sulphate	0·05	6·49	176·1	46·3	222·4	8·2

original pH, but left it slightly acid. Part of the carbonate could be seen as a fine white powder in the soil at the end of the experiment, showing that it had failed to react with the acid.

Lime alone gave small, but not very significant increases in crop, and increased the pH slightly.

Ammonium sulphate applied in a quantity sufficient to supply 0·05% sulphur, i.e., 26·7 cwts. per acre of the fertiliser, gave a greater increase in crop than the same quantity of sulphur applied as the element or as sulphuric acid either alone or with lime. It also increased the acidity to about the same amount as 0·1% sulphur applied in these other forms.

Disease.

The amount of soil-borne disease apparent in the crop was very small. A few plants were found affected with *Ophiobolus graminis* before harvest. Few disease organisms were observed developing on the bases of plants kept in damp chambers, but *Helminthosporium* sp. was found from four plots (control, calcium carbonate and two sulphur treated plots).

Discussion.

While the experimental evidence is insufficient to lead to definite conclusions, a consideration of possible factors leading to these remarkable increases in crop may be of value.

The apparent scarcity of soil-borne disease suggests that, contrary to the original supposition, factors other than disease were responsible for the poor crops obtained in recent years. And the fact that the diseases found were not more plentiful on the control than on the treated plots would seem to indicate that some factor other than the suppression of disease resulted in the large increases in crop obtained.

A general tendency is seen for increase in crops to accompany increase in soil acidity, but the fact that as good a crop is obtained with sulphuric acid followed by equivalent lime as with sulphuric acid alone indicates that yield does not depend directly on soil acidity. The acid, however, might dissolve compounds such as those of phosphorus, potassium, calcium and magnesium, making them more readily available to the plant, and if the soil were deficient in these compounds, increases in crop should result. The addition of lime might throw these compounds out of solution, but they would probably be left in a state more readily available to the plant than in the original soil.

Another possibility is that the original soil suffered from a sulphur deficiency, in which case similar increases in crop might result from sulphuric acid treatment applied alone or followed by lime, and from treatment with sulphur. Striking increases in crop, notably of alfalfa, have been obtained in Oregon (3), where large areas of soil appear to be deficient in sulphur.

The fact that ammonium sulphate gives a greater increase in crop than the same quantity of sulphur applied either as the element or as sulphuric acid suggests a deficiency of nitrogen. Some of the American work indicates a close relation between sulphur and nitrogen supply, suggesting that the former has a stimulating influence on the nitrogen-fixing bacteria. There may be a connection between this and the greater depth of green colour seen in the treated plots, which suggested the appearance of crops to which nitrogenous fertilisers had been applied.

Further investigation is desirable to discover the causes underlying the large increases in crop obtained.

From a practical point of view it seems very desirable that other soils should be examined to see whether they respond in a similar way.

Summary.

A plot of land on which wheat has been grown continuously for fourteen years has recently yielded poor crops.

Large increases in crop were obtained by soil treatment with equal quantities of sulphur applied as sulphur and as sulphuric acid.

Similar increases were obtained when calcium carbonate was applied after sulphuric acid, as when the acid was used alone.

Calcium carbonate alone gave a slight and relatively insignificant increase in crop.

Ammonium sulphate gave a larger crop than the same quantity of sulphur applied as the element or as sulphuric acid.

Only a small amount of disease was found, and this was no more common in the controls than in the untreated plots, so that the results appear to depend on non-pathological factors.

Although increase in crop is in general accompanied by increase in soil acidity the fact that the addition of lime did not depress the yield obtained with sulphuric acid suggests that soil acidity is not the chief factor. Acidity would, however, tend to bring other elements, such as phosphorus, potassium, calcium and magnesium, into solution, and though lime might throw these out of solution, they would probably be left in a state more readily available to the plant than in untreated soil.

A sulphur deficiency of the soil would explain the results obtained. Such a deficiency has been found in large areas in Oregon.

The larger increase in crop obtained with ammonium sulphate than with an equal quantity of sulphur as the element or the acid suggests a nitrogen deficiency.

The possibility is indicated that sulphur may have an effect on the nitrogen-fixing bacteria, which may be related to the dark green appearance of the treated plots.

Further investigations into the cause of the results obtained are desirable, and further investigations into other soils to see if they respond in the same way.

In conclusion, I would like to express my thanks to the many Australian friends who have done so much to facilitate my work while I have been in this country, and particularly to Professor Wadham, who has also extended to me the hospitality of his department.

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